PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F21V 8/00, 5/02 | A1

(11) International Publication Number: WO 96/11358

(43) International Publication Date: 18 April 1996 (18.04.96)

(21) International Application Number: PCT/US95/14272

(22) International Filing Date: 10 October 1995 (10.10.95)

(30) Priority Data:
08/321,368 11 October 1994 (11.10.94) US

(71) Applicant: ALLIEDSIGNAL INC. [US/US]; 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962-2245 (US).

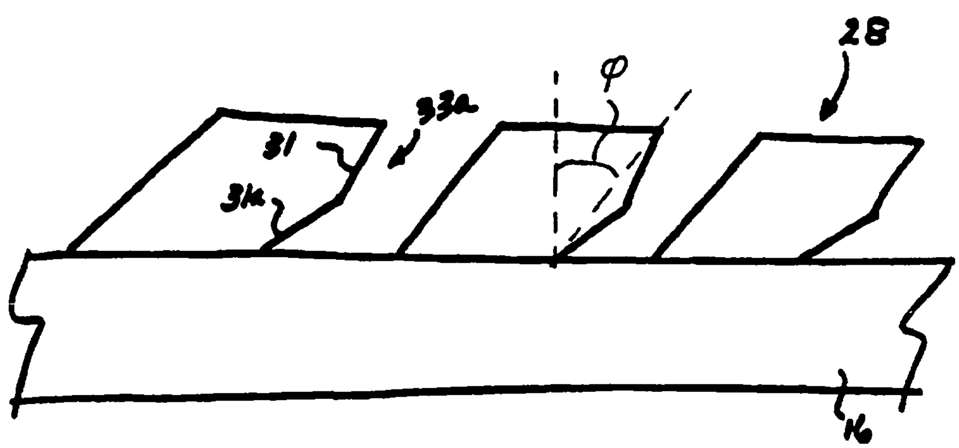
(72) Inventors: HOU, Janpu; 17 Kelly Court, Bridgewater, NJ 08807 (US). ZIMMERMAN, Scott, Moore; 40 Spring House Lane, Basking Ridge, NJ 07920 (US). BEESON, Karl, Wayne; 197 Dodds Lane, Princeton, NJ 08540 (US).

(74) Agent: CRISS, Roger, H.; AlliedSignal Inc., (Law Dept., Attn: C.A. McNally), 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962-2245 (US).

(81) Designated States: AU, CA, CN, FI, JP, KR, MX, SG, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

**Published**
*With international search report.*
*Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

(54) Title: ILLUMINATION SYSTEM EMPLOYING AN ARRAY OF MULTI-FACETED MICROPRISMS




**(57) Abstract**

An optical illumination system comprising a waveguide (16) that accepts light generated by a light source and transmits the light via total internal reflection. Attached on one face of the waveguide is an array of microprisms (28), with each microprism having a light input surface, a light output surface and at least one sidewall (33a) which is tilted at an angle $\rho$ from the direction normal to the surface of the waveguide (16) and further comprising at least two planar faces (31, 31a) such that light escapes from the waveguide (16), reflects off the tilted sidewalls (33a) and emerges from the microprism as a spatially directed light source. An array of microlenses may be positioned to accept the output of the microprisms (28) so that the light exiting from the microlenses is a substantially collimated light source. The optical illumination system is advantageous for any application that requires a non diffuse or substantially collimated light source that is both energy efficient and contained in a low profile assembly.

*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | |
|---|---|---|---|---|---|
| AT | Austria | GB | United Kingdom | MR | Mauritania |
| AU | Australia | GE | Georgia | MW | Malawi |
| BB | Barbados | GN | Guinea | NE | Niger |
| BE | Belgium | GR | Greece | NL | Netherlands |
| BF | Burkina Faso | HU | Hungary | NO | Norway |
| BG | Bulgaria | IE | Ireland | NZ | New Zealand |
| BJ | Benin | IT | Italy | PL | Poland |
| BR | Brazil | JP | Japan | PT | Portugal |
| BY | Belarus | KE | Kenya | RO | Romania |
| CA | Canada | KG | Kyrgystan | RU | Russian Federation |
| CF | Central African Republic | KP | Democratic People's Republic of Korea | SD | Sudan |
| CG | Congo | | | SE | Sweden |
| CH | Switzerland | KR | Republic of Korea | SI | Slovenia |
| CI | Côte d'Ivoire | KZ | Kazakhstan | SK | Slovakia |
| CM | Cameroon | LI | Liechtenstein | SN | Senegal |
| CN | China | LK | Sri Lanka | TD | Chad |
| CS | Czechoslovakia | LU | Luxembourg | TG | Togo |
| CZ | Czech Republic | LV | Latvia | TJ | Tajikistan |
| DE | Germany | MC | Monaco | TT | Trinidad and Tobago |
| DK | Denmark | MD | Republic of Moldova | UA | Ukraine |
| ES | Spain | MG | Madagascar | US | United States of America |
| FI | Finland | ML | Mali | UZ | Uzbekistan |
| FR | France | MN | Mongolia | VN | Viet Nam |
| GA | Gabon | | | | |

# ILLUMINATION SYSTEM EMPLOYING AN ARRAY OF MULTI-FACETED MICROPRISMS

## Cross Reference to Related Applications

This application is a continuation-in-part of U.S. Serial No. 08/242,525, filed on May 13, 1994 entitled "Illumination System Employing an Array of Microprisms" which is a continuation-in-part of U.S. Serial No. 08/149,219, filed on November 5, 1994, entitled "Backlighting Apparatus Employing an Array of Microprisms".

## Background of the Invention

This invention relates generally to an optical illumination system for collimating light that provides for relatively high light transmission. More particularly, the invention is directed to an illumination system having a plurality of optical microprisms and microlenses for redirecting light removed from a non-collimated light source and providing either separately or in combination a non-diffuse light source and a substantially collimated light source.

A number of optical and illumination applications require the production of either a non-diffuse or a collimated light source which provides an efficient output of light. Typical problems encountered with collimated light sources include: 1) a non-uniform light distribution; 2) a lack of a controlled directional output of light; 3) inefficiencies with regard to the amount of the collimated light output versus the amount of the non-collimated light input; and 4) the lack of an efficient collimated light source in a compact design or narrow profile.

Accordingly, there exists a need in the optical and illumination arts to provide an illumination assembly that provides an energy efficient light source while maintaining a narrow profile.

Summary of the Invention

The present invention is directed to an optical illumination system which provides either separately or in combination a non-diffuse light source and a substantially collimated light source (hereinafter referred to as a spatially directed light source) that is energy efficient. Additionally, this invention is directed to any lighting application that requires a low profile spatially directed light source.

The optical illumination system comprises a input light source optically coupled to a light transmitting means, a reflecting means for removing and redirecting the light from the light transmitting means wherein the reflecting means is optically coupled to the light transmitting means. The reflecting means comprises an array of microprisms, or in combination an array of microprisms in optical cooperation with an array of microlenses whereby the microprisms are operatively disposed between the light transmitting means and the microlenses. The reflecting means of the present invention provide an energy efficient distribution of spatially directed light that is provided in a low profile assembly.

In one preferred embodiment, a single input light source is positioned adjacent to a light accepting surface of the light transmitting means. The light transmitting means may be any structure that transmits light via reflection, such as a light pipe, light wedge, waveguide or any other structure known to those skilled in the art. Preferably the light transmitting means comprises a waveguide that accepts the light generated by the input light source and transports the light via total internal reflection (TIR). Attached on one face of the waveguide is an array of microprisms. The microprisms comprise a light input surface in optical cooperation with the waveguide and a light output surface distal to and parallel with the light input surface. The microprisms further comprise four sidewalls wherein each sidewall comprises a planar face. The four sidewalls are angled in such a way with respect to the normal of the surface of the light transmitting means that light traveling through the waveguide is captured and redirected by the microprisms, reflects through the microprisms via TIR and emerges from the microprisms as a spatially directed light source. A spatially directed light source is meant to include a substantially collimated light source in a direction substantially perpendicular to the to the light output surface or a light source directed at a controlled angle with respect to the normal of the light output surface. Alternatively, at least one of the sidewalls comprises two or more planar reflective faces to improve the reflectivity of the microprism. The number of planar faces forming the sidewall may become infinitesimally minute such that all or part of the sidewall is arcuately shaped.

In an alternate embodiment, an array of microlenses is operatively disposed adjacent to the light output surface of the microprisms. The microlenses are formed with a proper curvature and positioned so that the light emanating from each microprism is directed to a corresponding microlens. The light transmits through the microlenses and emerges as a substantially more collimated light source.

In another preferred embodiment two input light sources are positioned adjacent to oppositely disposed light accepting surfaces of the light transmitting means. The light transmitting means comprises a waveguide that accepts the light generated by both input light sources and transports the light via TIR. Attached on one face of the waveguide is an array of microprisms. The microprisms comprise a light input surface in contact with the waveguide and a light output surface distal to and parallel with the light input surface wherein the surface area of the light output surface is greater than the surface area of the light input surface. The microprisms further comprise four tilted sidewalls with each sidewall comprising a planar face. The sidewalls are angled in such a way that light traveling in the waveguide from both input light sources is captured and redirected by the microprisms, reflects through the microprisms via TIR and emerges from the microprisms as a spatially directed light source. Alternatively, at least one sidewall comprises multiple planar reflective faces.

In still another alternate embodiment, an array of microlenses is operatively disposed adjacent to the light output surface of the microprisms. The microlenses are formed with a curvature and positioned so that the light emanating from each microprism is directed to a corresponding microlens or a plurality of microlenses. The light transmits through the microlenses and emerges as a substantially more collimated light source.

There are many illumination applications that can take advantage of such an illumination system employing such an arrangement of microprisms and microlenses. Such applications exist in the automotive industry, the aerospace industry and the commercial and residential markets. Some automotive applications, by way of example only and not intended to limit the possible applications include: low profile car headlights and taillights; low profile interior car lights such as reading lights and map lights; light sources for dashboard displays;

backlights for flat panel navigation displays, flat panel auto TV screens and flat panel electronic instrument displays; traffic lights; and backlights for road signs. Illustrative examples in the aerospace industry include backlights for flat panel cockpit displays and flat panel TV screens in the passenger section of the aircraft; low profile reading lights and aircraft landing lights; and runway landing lights. Residential and commercial applications include low profile interior and exterior spotlights and room lighting with a high or a low degree of collimation; backlights for flat panel TV screens, LCD displays, such as computers, game displays, appliance displays, machine displays, picture phones, advertisement displays, light for show case displays and point-of-purchase displays.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

Brief Description Of The Drawings

The above and other objects and advantages of this invention will be apparent on consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which like reference characters refer to like parts throughout, and in which:

FIGURE 1 is an elevation view of one embodiment of the present invention in conjunction with a single input light source;

FIGURE 1A is an exploded view of the embodiment of Fig. 1;

FIGURE 1B is a side view of the embodiment of Fig. 1;

FIGURE 2A-2C are alternate shape embodiments of a single microprism specific for a single light source input;

FIGURE 3 is an elevation view of the embodiment of Fig. 1 including an array of microlenses;

FIGURE 3A is a side view of the embodiment of Fig. 3;

FIGURES 4 and 4A are exploded views of a single microlens;

FIGURE 5 is an elevation view of an alternate embodiment of the present invention in conjunction with two input light sources;

FIGURE 5A is an exploded side view of the embodiment of Fig. 5;

FIGURES 6A-6C are alternate shape embodiments of a single microprism for application with dual light source inputs;

FIGURES 7A and 7B are further alternate shape embodiments of a single microprism for application with dual light source inputs;

FIGURE 8 is an elevation view of the embodiment of Fig. 5 including an array of microlenses;

FIGURE 9 is an exploded view of the embodiment of Fig. 8; and

FIGURE 10 is a side view of the embodiment of Fig. 5.

Detailed Description of the Preferred Embodiments

The preferred embodiments of the present invention will be better understood by those skilled in the art by reference to the above figures. The preferred embodiments of this invention illustrated in the figures are not intended to be exhaustive or to limit the invention to the precise form disclosed. They are chosen to describe or to best explain the principles of the invention and its applicable and practical use to thereby enable others skilled in the art to best utilize the invention.

One preferred embodiment of the present invention is shown in Figs. 1, 1A and 1B. An illumination system, represented by the number 2, comprises a light generating means 14, a waveguide 16 having a light accepting surface 17 and a transparent reflecting means 18 in optical contact with waveguide 16. Examples of useful light generating means 14 include lasers, fluorescent tubes, light emitting diodes, incandescent lights, sunlight and the like which may also be combined with reflection means to increase the optical coupling. The waveguide 16 is made from any transparent material such as glass or polymer. In Fig. 1, light generating means 14 is optically coupled to waveguide 16, and reflecting means 18 is in contact with wave guide 16.

The reflecting means 18 comprises an optional adhesion promoting layer 26 and an array of microprisms 28. Light reflects through waveguide 16 via TIR and enters each microprism 28 by way of light input surface 30, reflects off sidewalls 33, 35 and 37 and exits the microprism 28 through the light output surface 32 as a spatially directed light source.

Waveguide 16 is transparent to light within the wavelength range from about 400 to about 700 nm.. The index of refraction of the waveguide 16 may range from about 1.40 to about 1.65. The most preferred index of refraction is from about 1.45 to about 1.60. The waveguide 16 may be made from any transparent solid material. Preferred materials include transparent polymers. glass and fused silica. Desired characteristics of these materials include mechanical and optical stability at typical operation temperatures of the device. Most preferred materials are glass, acrylic, polycarbonate and polyester.

Microprisms 28 can be constructed from any transparent solid material. Preferred materials have an index of refraction equal to or greater than waveguide 16. Preferred materials have a refractive index between about 1.40 and about 1.65. One method of manufacturing microprisms 28 includes injection molding. Materials useful in this method include polycarbonate, acrylic and poly(4-methyl pentene). Alternate methods of manufacture may include polymers formed by photopolymerization of acrylate monomer mixtures composed of urethane acrylates and methacrylates, ester acrylates and methacrylates, epoxy acrylates and methacrylates, (poly) ethylene glycol acrylates and methacrylates and vinyl containing organic monomers. Useful monomers include methyl methacrylate, n-butyl acrylate, 2-ethylhexyl acrylate, isodecyl acrylate, 2-hydroxyethyl acrylate, 2-hydroxypropyl acrylate, cyclohexyl acrylate, 1,4-butanediol diacrylate, ethoxylated bisphenol A diacrylate, neopentylglycol diacrylate, diethyleneglycol diacrylate, diethylene glycol dimethacrylate, 1,6-hexanediol diacrylate, trimethylolpropane triacrylate, pentaerythritol triacrylate and pentaerythritol tetra-acrylate. Especially useful are mixtures wherein at least one monomer is a multifunctional monomer such as diacrylate or triacrylate, as these will produce a network of crosslinks within the reacted photopolymer. The most preferred materials for microprisms 28 formed by photolithography are crosslinked polymers formed by photopolymerizing mixtures of ethoxylated bisphenol A diacrylate and trimethylolpropane triacrylate.

Microprisms 28 are separated by interstitial regions 36. The index of refraction of interstitial regions 36 must be less than the index of refraction of the microprism 28. Preferred materials for interstitial regions include air, with an index of refraction of 1.00 and fluoropolymer materials with an index of refraction ranging from about 1.16 to about 1.40. The most preferred material is air.

The optional adhesion promoting layer 26 is an organic material that is light transmissive and that causes the microprisms 28, however manufactured, such as formed from polymers, as for example photocrosslinked acrylate monomer materials or injection molded polycarbonate, to adhere strongly to the waveguide 16. Such materials are well known to those skilled in the art. The thickness of adhesion promoting layer 26 is not critical and can vary widely. In the preferred embodiment of the invention, adhesion layer 26 is less than about 30 micrometers thick.

The microprisms may be arranged in any pattern on waveguide 16, such as in a square, rectangular or hexagonal pattern. The microprisms have a repeat distance 38 (Fig. 1) in the direction perpendicular to light accepting surface 17 and repeat distance 40 (Fig. 1B) in the direction parallel to light accepting surface 17. Repeat distances 38 and 40 may be equal or unequal and may vary widely depending on the resolution and dimensions of the display. In addition, the repeat distances 38 and 40 may vary across the surface of the waveguide 16 in order to compensate for a lowering of the light intensity inside waveguide 16 as the distance from light generating means 14 increases. This lowering of the light intensity is due to light removal by the other microprisms of the array.

The microprisms 28 are constructed to form a six-sided geometrical shape having a light input surface 30 preferably parallel with a light output surface 32, wherein the light output surface 32 is equal to or larger in surface area than the light input surface 30. Microprism 28 further comprises two pairs of oppositely disposed sidewalls 33, 34 and 35, 37, wherein each sidewall comprises a planar reflective face. Preferably, each sidewall is effective in reflecting and redirecting the light which is propagating through waveguide 16. Preferably, the intersection of sidewall 33 with waveguide 16, or adhesion layer 26 thereon, forms a line that is perpendicular to the average direction of the light. For example, as shown in Fig. 1, the intersection of sidewall 33 with adhesion layer 26 forms a line parallel to the light accepting surface 17 and is therefore perpendicular to the average direction of the light traveling through the waveguide 16.

As shown in Fig. 1A, each microprism 28 is formed so that sidewall 33 forms a tilt angle $\varphi$ to the normal of the surface of waveguide 16. The desired values of tilt angle $\varphi$ range from about 15 degrees to about 50 degrees. More preferred values for tilt angle $\varphi$ range from about 20 degrees to about 40 degrees. As will be obvious to those skilled in the art, tilt angle $\varphi$ determines at which angle with respect to the normal of the light output surface the spatially directed light will emerge.

Referring to Fig. 1B, sidewalls 35 and 37 also form a tilt angle θ to the normal of the surface of waveguide 16. The desired values of tilt angle θ range from about 0 degrees to about 25 degrees. More preferred values for tilt angle θ range from about 2 degrees to about 20 degrees. Preferably, the tilt angles θ associated with sidewalls 35 and 37 are equal, but equal angles are not necessary.

Alternatively, at least one side wall of microprism 28 comprises two or more planar reflective faces to improve the reflectivity of the microprism. Fig. 2A illustrates sidewall 33a having two planar faces 31 and 31a. The number of planar faces that form a sidewall may vary. Fig. 2B shows a still alternate embodiment where at least one sidewall comprises multiple planar faces infinitesimally minute such that sidewall 33b is arcuately shaped. Alternatively, in Fig. 2C, sidewall 33c comprises an arcuate-shaped reflective surface 42 and a planar reflective surface 42a.

Referring again to Figs. 1A, 1B and 1C, the height of microprism 28 has dimension 50. Height 50 may vary widely depending on the dimensions and resolution of the display. That is, smaller displays, such as laptop computer displays and avionics displays would have greatly reduced dimensions versus larger displays such as large screen, flat-panel televisions.

The length of microprism 28 has dimensions 52 and 53. Length 52 corresponds to the light input surface 30 and length 53 corresponds to the light output surface 32. Length 53 can be equal to or greater than length 52. Lengths 52 and 53 may vary widely depending on the dimensions and resolution of the display. In addition, the length 52 may vary across the surface of the light transmitting means 16 in order to compensate for a lowering of the light intensity inside waveguide 16 as the distance from light generating means 14 increases. That is, microprisms 28 that are closer to light generating means 14 may have a smaller dimension 52 as compared to microprisms farther from light generating means 14. This lowering of the light intensity is due to light removal by the other microprisms of the array. The maximum value for lengths 52 and 53 is less than the repeat distance 38 of Fig. 1.

Microprism 28 has width dimensions 54 and 55 where width 54 corresponds to the light input surface 30 and width 55 corresponds to the light output surface 32. Widths 54 and 55 may vary widely depending on the dimensions and resolution of the display and are a function of tilt angle θ and height 50. In addition, the width 54 may vary across the surface of the light transmitting means 16 in order to compensate for a lowering of the light intensity inside waveguide 16 as the distance from light generating means 14 increases. The maximum value for widths 54 and 55 is less than the repeat distance 40. It is desirable that length dimension 52 be larger than width dimension 54. It is preferred that the ratio of length 52 to width 54 be in the range of 1.2:1 to 5:1. It is more preferred that the ratio be in the range of 1.5:1 to 3:1.

In an alternate embodiment, reflecting means 18 further comprises an array of microlenses 80 as shown in Figs. 3 and 3A. The microlenses 80 are optically coupled to the microprisms 28. Microlenses 80 may be fabricated using the same techniques as described for microprisms 28. If the microlenses 80 are fabricated by photopolymerization, they are preferably made from the same monomers as those previously disclosed for the microprisms 28 and have a index of refraction equal to or substantially equal to the index of refraction of the microprisms 28. However, any transparent material may be used, as for example, those materials previously discussed. The center-to-center distance between microlenses directly correlates to the repeat distances 38 and 40 of the microprisms 28. That is, for every microprism 28 there exists a corresponding microlens 80 that aligns with the output surface 32 of each microprism 28.

A spacer 82 separates the microlenses 80 and the microprisms 28. The thickness of spacer 82 is optimized to cause light from microprisms 28 to be collimated by microlenses 80. Spacer 82 may be made from any transparent material. Preferred materials include transparent polymers, glass and fused silica. Preferably spacer 82 has an index of refraction equal to or substantially equal to the index of refraction of the microprisms 28 and the microlenses 80. Desired characteristics of these materials include mechanical and optical stability at typical operation temperatures of the device. Most preferred materials are glass, acrylic, polycarbonate, polyester and photopolymerized acrylate monomers..

A single microlens 80 is shown in Fig. 4. The microlens can be either a spherical lens or an aspherical lens or an astigmatic lens. The footprint of a microlens 80 is not necessarily circular, but can be rectangular in shape, as shown in Fig. 4A , having a length 86 and width 87 that are respectively equal in length with repeat distances 38 and 40.

If microlens 80 is a spherical lens, the lens will have one curved surface having a radius of curvature 84. The radius of curvature can vary widely depending on the repeat distances 38 and 40 of the corresponding microprism array. In order that microlens 80 collect substantially all of the light directed out of waveguide 16 by microprism 28, the f-number of microlens 80 should be relatively small. The f-number values for microlens 80 can range from about 0.5 to about 4.0. More preferred values for the f-number range from about 0.6 to about 3.0.

Another alternate embodiment of the invention is shown in Figs. 5 and 5A. Two light generating means 14 and 14A are positioned adjacent to two oppositely disposed light accepting surfaces 17 and 17A of the waveguide 16. In addition to the illustrative light generating means, one of the light generating means may be a reflective surface. The reflective surface acts as a light source by reflecting light from the other light source into light transmitting means 16. An array of microprisms 90 are attached to the waveguide 16 in a similar manner disclosed above. The microprisms 90 comprise a light input surface 92 preferably parallel to a light output surface 94 wherein the light output surface 94 is larger in surface area than the light input surface 92. Microprism 90 also comprises two pairs of oppositely disposed tilted sidewalls 96, 98 and 97, 99.

Sidewalls 96 and 98 are each formed at the angle $\varphi$ to the normal of the surface of waveguide 16. Preferably, the tilt angles $\varphi$ associated with sidewalls 96 and 98 are equal, but equal tilt angles are not necessary. Preferably, the intersection of each tilted sidewall 96 and 98 with the waveguide 16, or adhesion layer 26 thereon, is parallel to the oppositely disposed light accepting surfaces 17 and 17A, and therefore, perpendicular to the average direction of the light traveling through the waveguide 16.

Referring to Fig. 5A, sidewalls 97 and 99 are each formed at the angle $\theta$ to the normal of the surface of waveguide 16. Preferably, the tilt angles $\theta$ associated with sidewalls 97 and 99 are equal, but equal angles are not necessary. The intersection of each tilted sidewall 97 and 99 with the waveguide 16 or adhesion layer 26 thereon, is perpendicular to the oppositely disposed light accepting surfaces 17 and 17A, and therefore, parallel to the average direction of the light traveling through the waveguide 16.

Alternatively, at least one side wall of microprism 90 comprises one or more planar reflective faces to improve the reflectivity of the microprism. Fig. 6A illustrates sidewall 98a having two planar faces 95 and 95a. In one embodiment, sidewalls 96a, 98a, 97a and 99a may comprise at least two planar reflective faces as illustrated in Figs. 6B and 6C Generally however, microprism 90 may have any combination of planar sidewalls and sidewalls having two or more planar faces.

Figs. 7 and 7A show a further embodiment where at least one sidewall, for example 98b, comprises multiple planar faces infinitesimally minute such that sidewall 98b is arcuately shaped. Alternatively, sidewall 98b comprises an arcuate-shaped reflective surface 93 and a planar reflective surface 93a.

The height of microprism 90 has dimension 110 and is similar to height 50 of microprism 28. The length of microprism waveguide 90 has dimensions 120 and 122 where dimension 122 is less than dimension 120. Both lengths 120 and 122 are a function of tilt angle φ and height 110. Lengths 120 and 122 may vary widely depending on the dimensions and resolution of the display. In addition, the lengths 120 and 122 may vary across the surface of the light transmitting means 16 in order to compensate for a lowering of the light intensity inside waveguide 16 as the distance from light generating means 14 and 14A increases. The maximum value for the length 120 is less than the repeat distance 138.

The width of microprism 28 has dimensions 130 and 132 as shown in Fig. 5A. Dimension 132 is less than or equal to dimension 130. Both widths 130 and 132 are a function of tilt angle θ and height 110. Widths 130 and 132 may vary widely depending on the factors discussed above for lengths 120 and 122. The maximum value for the width 130 is less than the repeat distance 140. It is desirable that length dimension 122 be larger than width dimension 132. It is preferred that the ratio of length 122 to width 132 be in the range of 1.2:1 to 5:1. It is more preferred that the ratio be in the range of 1.5:1 to 3:1.

An still further alternate embodiment of the invention, disclosed in Figs. 8 through 10, comprises an array of microlenses 80 optically coupled to microprisms 90. A spacer 82 separates the microlenses 80 from microprisms 90 as previously disclosed. The light emerges from each microprism 90 as a spatially directed light source and inputs into one or more microlenses. Preferably, the light source is directed to two microlenses. The spatially directed light source emanating from the microprisms 90 is collimated by the microlenses 80 to provide a substantially collimated light pattern. The center-to-center distance between microlenses directly correlates to the repeat distances 138 and 140 of the microprisms 90. The length

86 (Fig. 4A) of each microlens 80 aligns with respect to the microprism array so that equal distances overlap adjacent microprisms as shown in Figs. 8 and 9 The width 87 of each microlens aligns with respect to a single microlens as shown in Fig. 10.

Arrays of microprisms 28 and 90 and microlenses 80 can be manufactured by any number of techniques such as molding, including injection and compression molding, casting, including hot roller pressing casting, photopolymerization within a mold and photopolymerization processes which do not employ a mold. A preferred manufacturing technique would be one that allows the reflecting means 18 which comprises an array of microprisms 28 or 90, an array of microlenses 80 and a spacer 82 to be manufactured as a single integrated unit. An advantage of this technique would be the elimination of alignment errors between the array of microprisms and microlenses if the arrays were manufactured separately and then attached in the relationship described above.

It will be understood that the particular embodiments described above are only illustrative of the principles of the present invention, and that various modifications could be made by those skilled in the art without departing from the scope and spirit of the present invention, which is limited only by the claims that follow.

What is claimed is:

1. An illumination assembly for providing a spatially directed light source comprising:

(a) a light transmitting means having a first light accepting surface optically coupled to a first light source, wherein said light transmitting means transports light emanating from said first light source;

(b) reflecting means for redirecting said light comprising an array of microprisms wherein each microprism comprises:

(i) a light input surface optically coupled to said light transmitting means;

(ii) a light output surface distal from said light input surface and having a surface area at least equal to the surface area of said light input surface;

(iii) a first pair of oppositely disposed sidewalls disposed between and contiguous with said light input surface and said light output surface and at least one of said sidewalls forms a first tilt angle with respect to the normal of the surface of said light transmitting means and further comprises at least two planar reflective faces; and

(iv) a second pair of oppositely disposed tilted sidewalls, disposed between and contiguous with said light input surface and said light output surface;

wherein, said light reflecting through said light transmitting means enters said microprisms through said light input surfaces, is redirected by said sidewalls and emerges through said light output surfaces as a spatially directed light source.

2. The illumination assembly of claim 1 wherein at least one of said sidewalls of said second pair forms a second tilt angle with respect to the normal of the surface of said light transmitting means.

3. The illumination assembly of claim 2 wherein at least one of said sidewalls of said second pair comprises at least two planar reflective faces.

4. The illumination assembly of claim 1 wherein said sidewall having at least two planar faces is arcuately shaped.

5. The illumination assembly of claim 1 wherein said reflecting means further comprises an array of microlenses, wherein the output of each microprism is directed to at least one corresponding microlens and said light transmitted through said microlenses emerges as a substantially collimated light source.

6. The illumination assembly of claim 5 wherein said microprisms and microlenses are constructed from organic polymeric material.

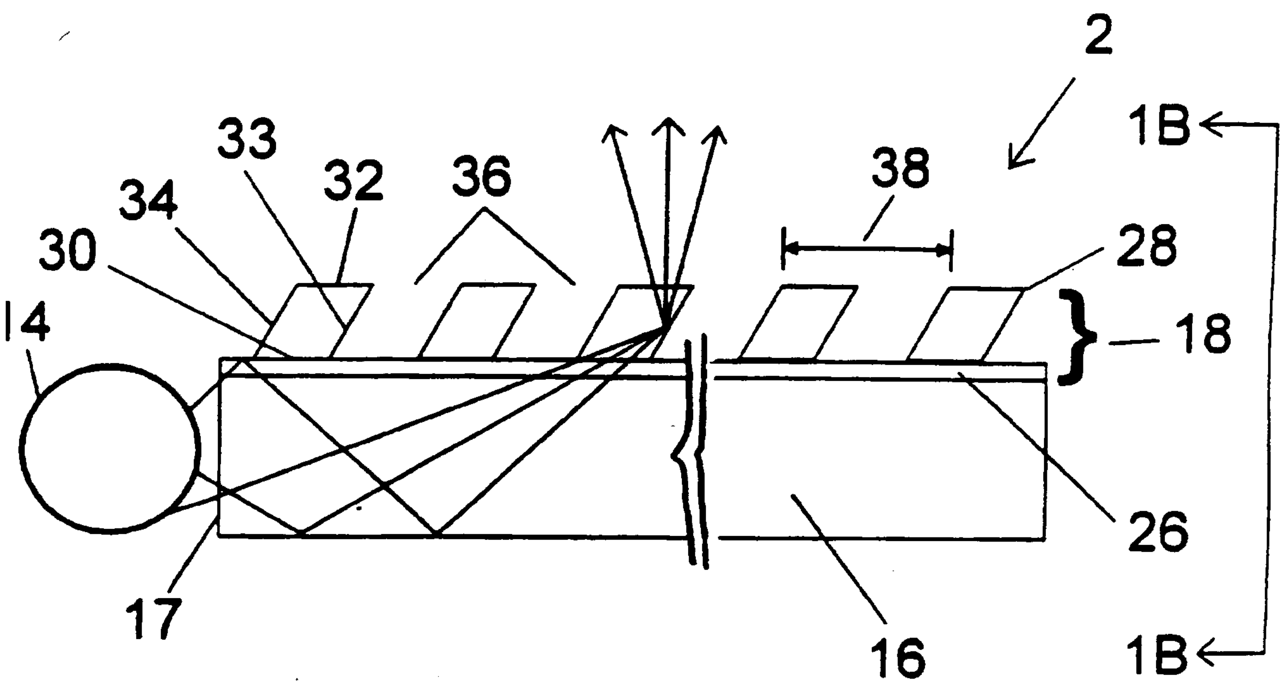
7. The illumination assembly of claim 1 wherein said first tilt angle is between 15 to 50 degrees to the normal of the surface of said light transmitting means.

8. The illumination assembly of claim 2 wherein said second tilt angle is between 2 to 20 degrees.

9. The illumination assembly of claim 5 wherein said microprisms, microlenses, and light transmitting means have an index of refraction of between about 1.45 and about 1.65.

10. The illumination assembly of claim 9 further comprising an interstitial region between said microprisms having an index of refraction less than the index of refraction of said microprisms.

# FIG. 1



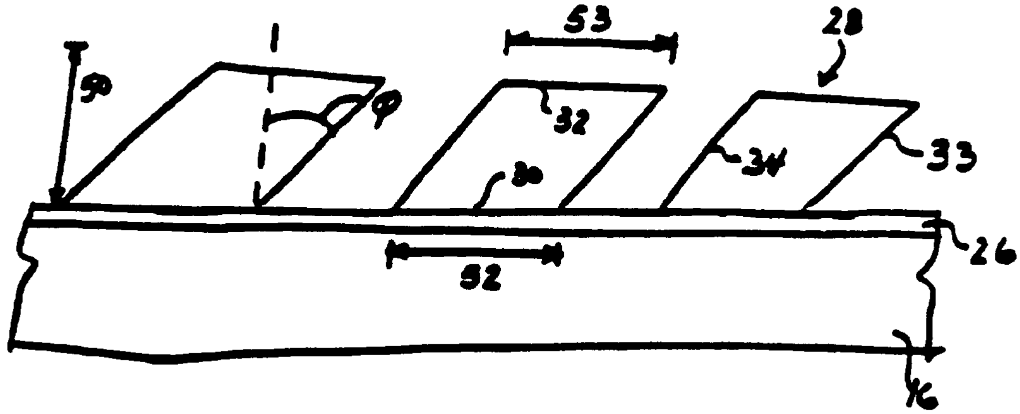



FIG. 1A

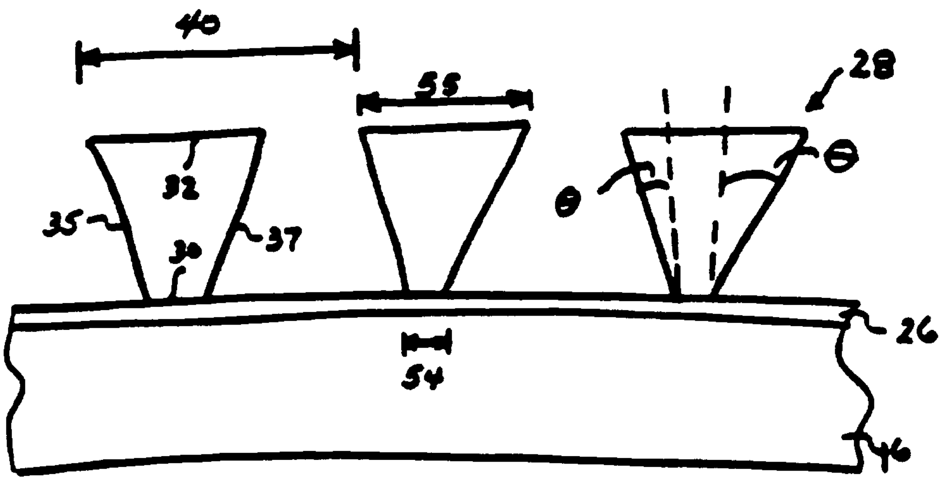



FIG. 1B

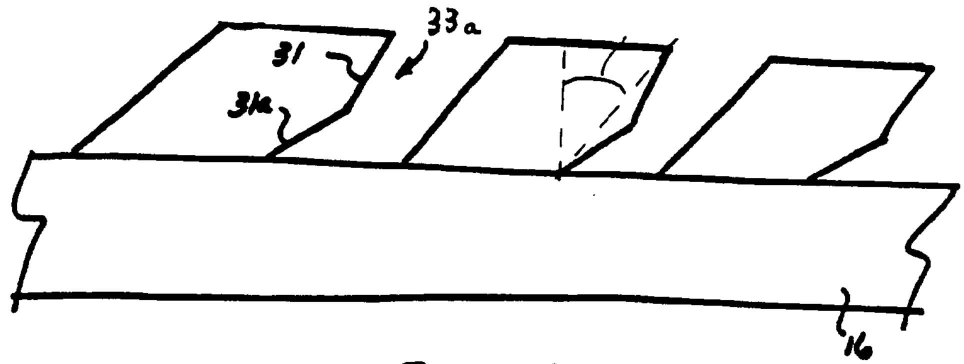



FIG. 2A

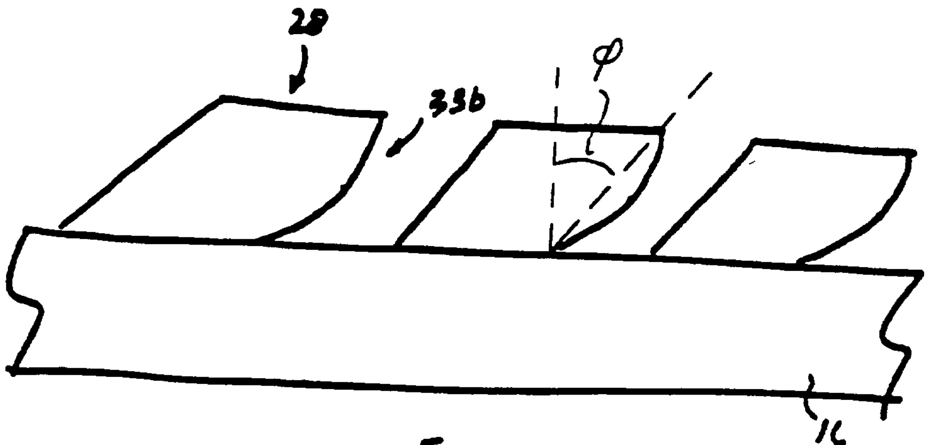



FIG. 2B

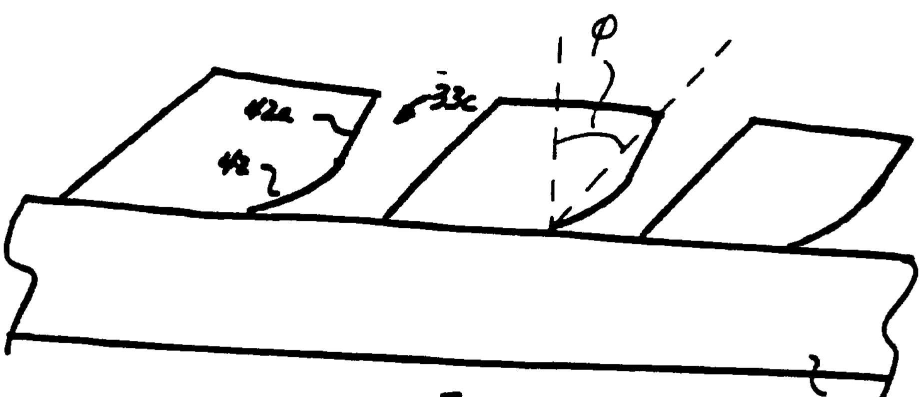
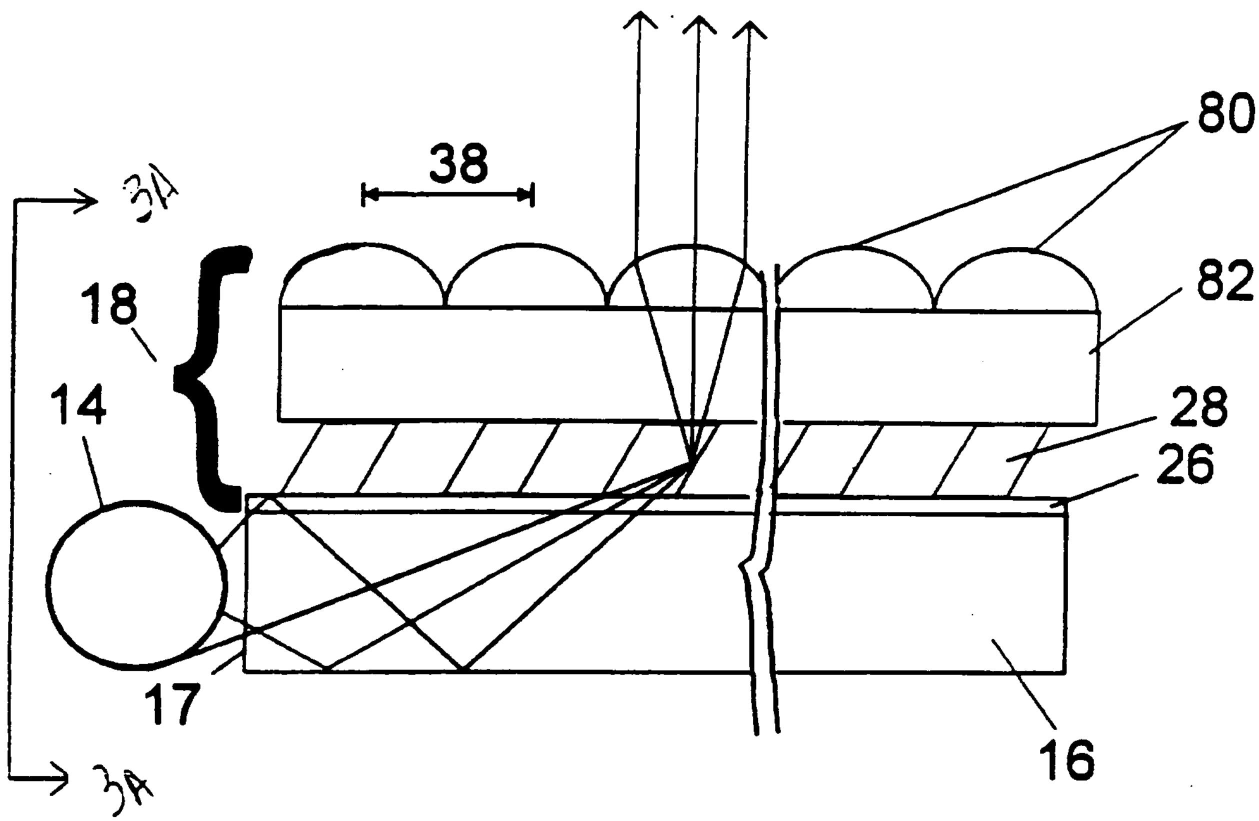



FIG. 2C

# FIG. 3



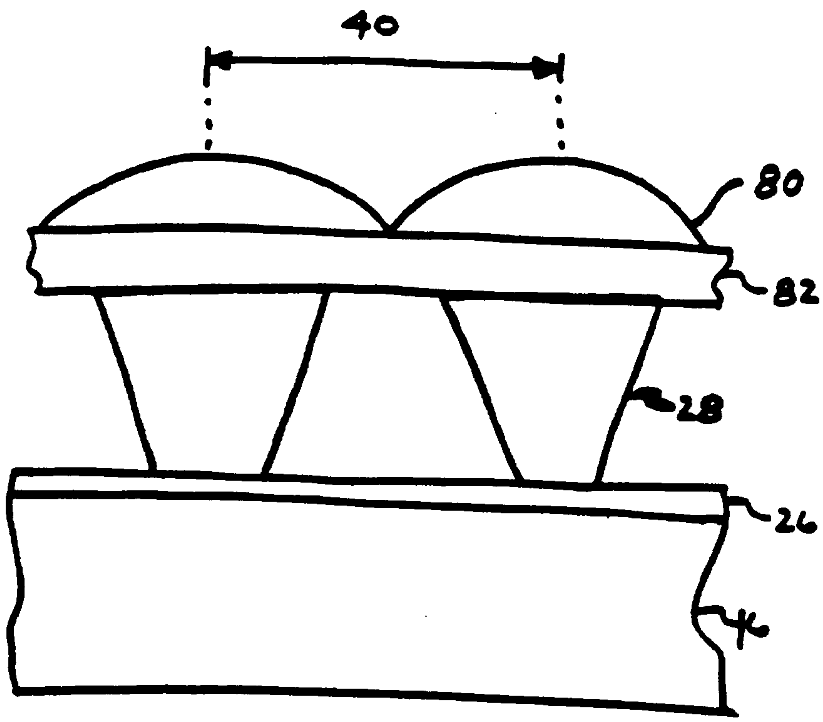



FIG. 3A

FIG. 4

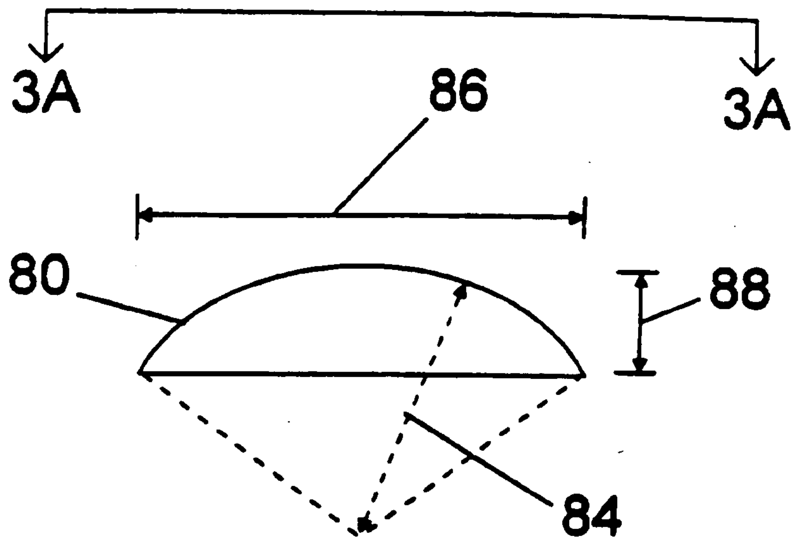



FIG. 4A

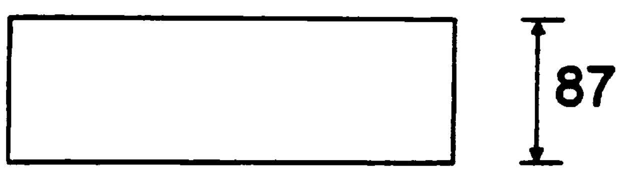
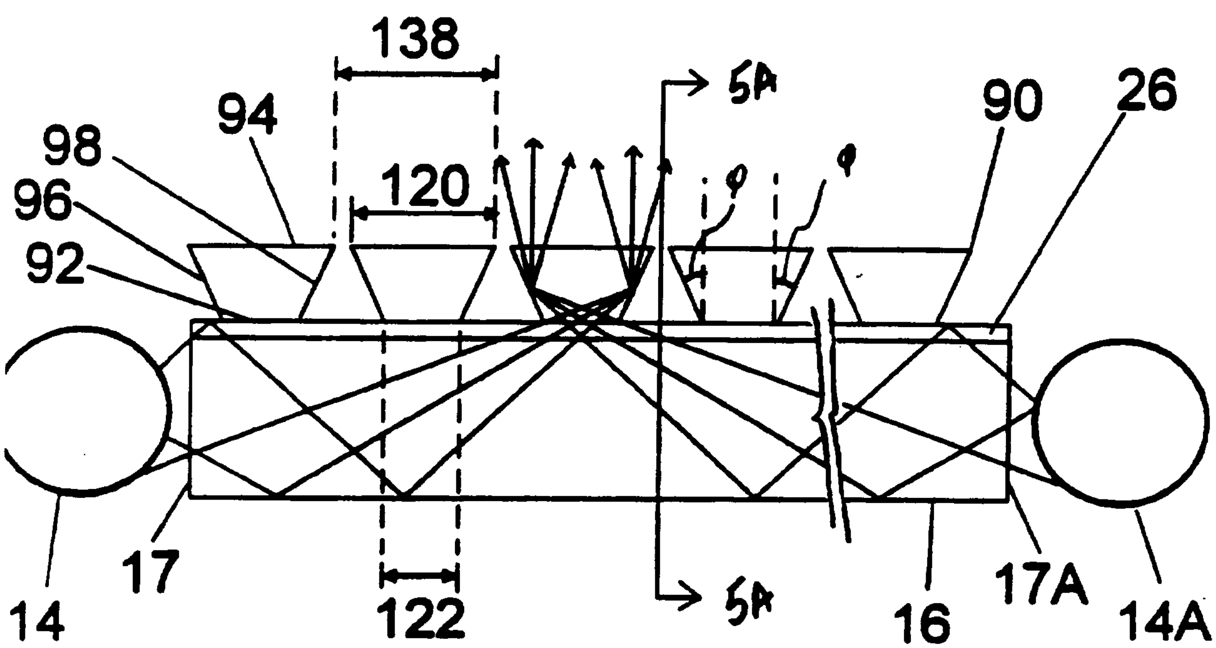


FIG. 5



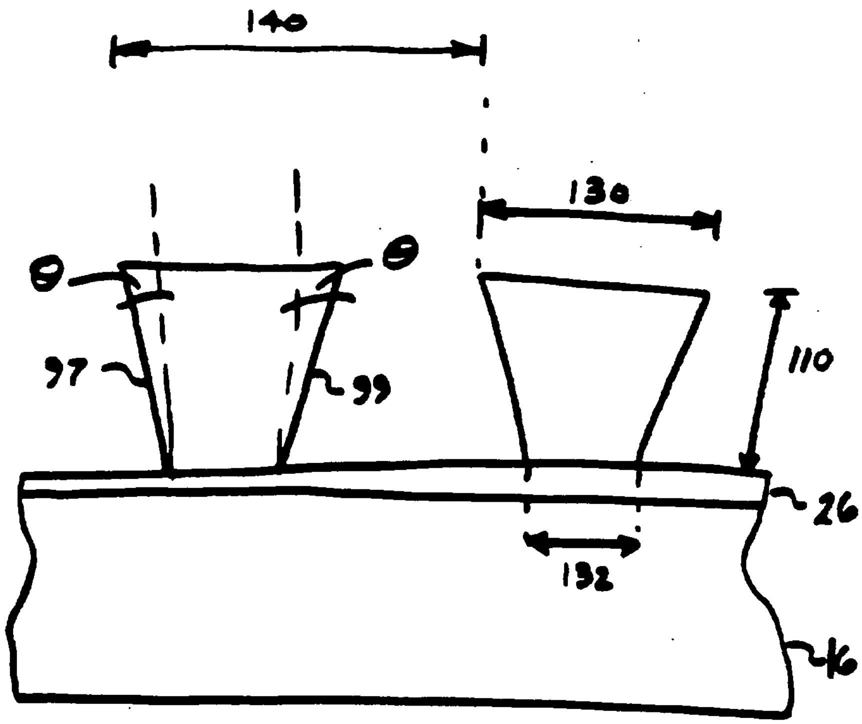



FIG. 5A

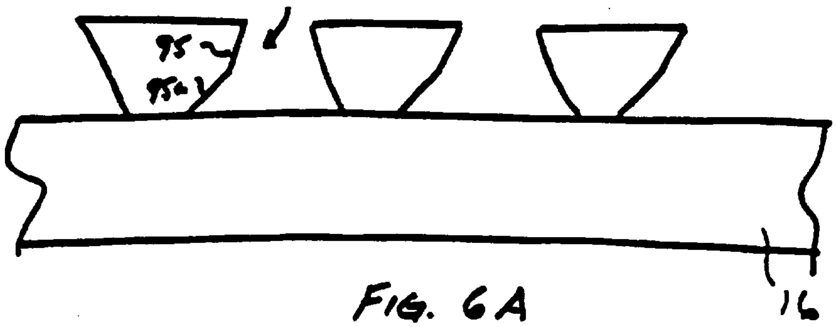



FIG. 6A

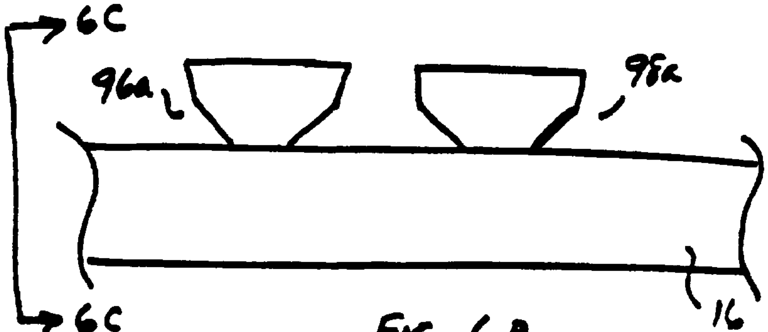



FIG. 6B

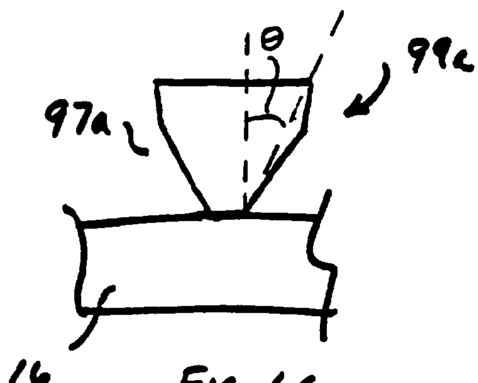



FIG. 6C

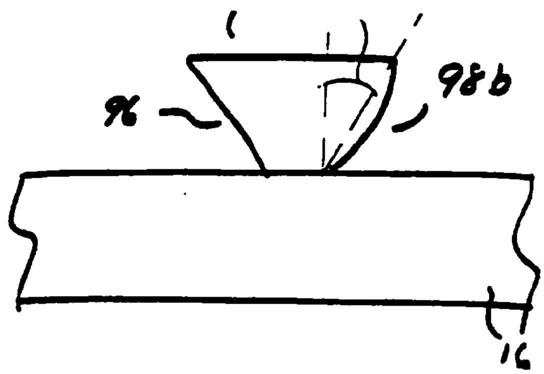



FIG. 7A

11/13

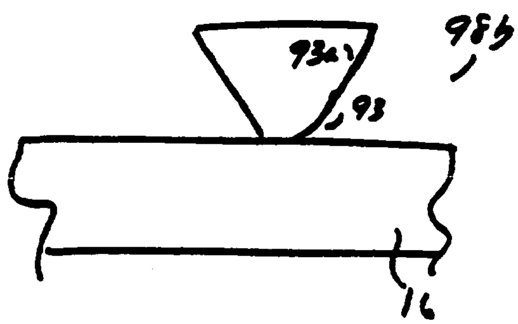



FIG. 7B

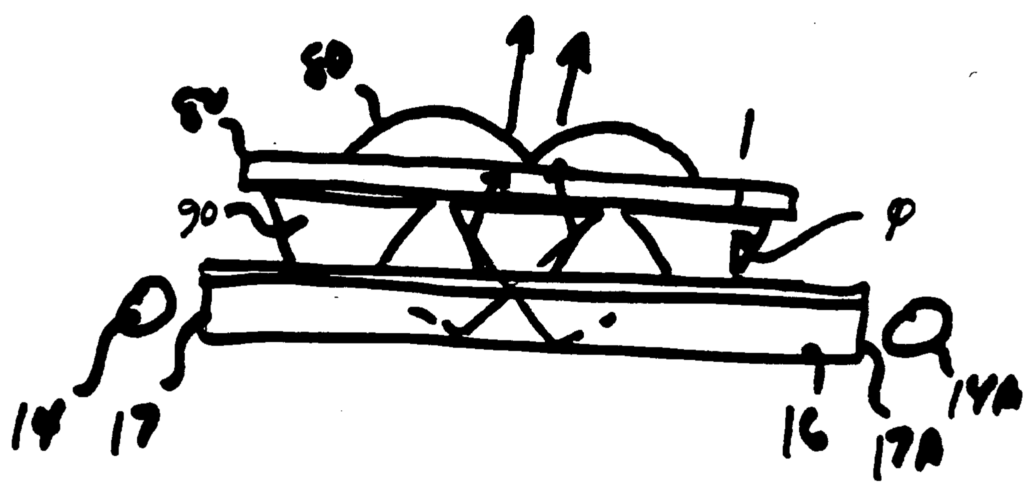



FIG. 8

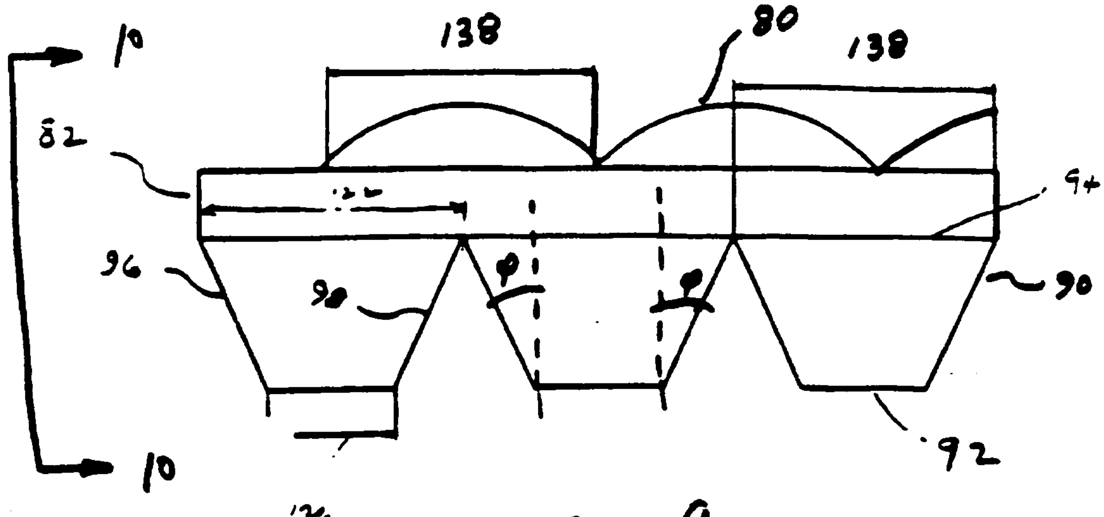



FIG. 9

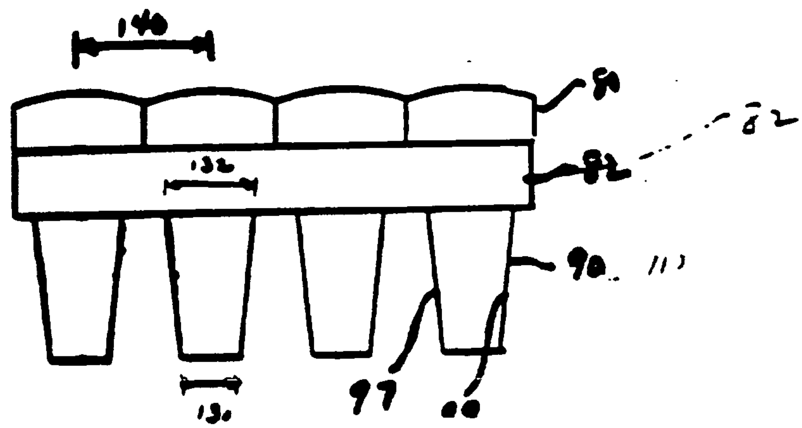



FIG. 10

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/14272

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 F21V8/00 F21V5/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F21V G09F G02F G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| P,Y | US,A,5 396 350 (BEESON KARL W ET AL) 7 March 1995<br>cited in the application<br>see claims 1-3,5,7,8,10,11; figures 2-3D,7,8,14<br>--- | 1-3,5-7, 9,10 |
| Y | EP,A,0 292 159 (MINNESOTA MINING & MFG) 23 November 1988<br>see column 3, line 15 - line 43; figures 3,4<br>--- | 1-3,5-7, 9,10 |
| A | US,A,5 040 878 (EICHENLAUB) 20 August 1991<br>see column 3, line 44 - line 50<br>see column 4, line 9 - line 26<br>see column 4, line 62 - column 5, line 14<br>see column 7, line 20 - line 24<br>see column 7, line 37 - line 51; figures 1-4,6-8<br>---<br>-/-- | 1,4 |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 15 March 1996 | 21.03.96 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Martin, C |

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Int ional Application No
PCT/US 95/14272

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | EP,A,0 154 847 (CARL ZEISS-STIFTUNG HANDELND ALS CARL ZEISS) 18 September 1985<br>see abstract<br>see page 5, line 1 - line 5; figure 1C<br>--- | 1 |
| A | DE,A,27 36 486 (IZON CORP.) 16 February 1978<br>see page 10, line 8 - page 11, line 3; figures 4,5<br>--- | 1,5 |
| A | IBM TECHNICAL DISCLOSURE BULLETIN, vol. 33, no. 9, February 1991 NEW YORK US,<br>pages 261-262, XP 000109498 'high efficiency back light for lcd'<br>see the whole document<br>----- | 1 |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 95/14272

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US-A-5396350 | 07-03-95 | AU-B- 1087795 | 23-05-95 |
| | | WO-A- 9512782 | 11-05-95 |
| | | US-A- 5428468 | 27-06-95 |
| EP-A-0292159 | 23-11-88 | AU-B- 613032 | 25-07-91 |
| | | AU-B- 1562788 | 10-11-88 |
| | | AU-B- 7735591 | 15-08-91 |
| | | CA-A- 1316159 | 13-04-93 |
| | | DE-D- 3850705 | 25-08-94 |
| | | DE-T- 3850705 | 02-02-95 |
| | | ES-T- 2056106 | 01-10-94 |
| | | JP-A- 63298902 | 06-12-88 |
| | | US-A- 4984144 | 08-01-91 |
| US-A-5040878 | 20-08-91 | EP-A- 0515723 | 02-12-92 |
| EP-A-154847 | 18-09-85 | DE-A- 3406191 | 26-09-85 |
| DE-A-2736486 | 16-02-78 | JP-A- 53047822 | 28-04-78 |